chapter **iii**

Why Attaining the Current Tidal-Water Designated Uses Appears Not to be Feasible

BACKGROUND

Many natural biological, physical and chemical processes and interactions influence water quality conditions and physical habitats in the Chesapeake Bay and its tidal tributaries. In addition, the watershed and estuary have changed dramatically, and in many ways, irreversibly, over the last four centuries as the population has grown to nearly 16 million people. The current state designated uses cannot be met in the deeper waters of the Chesapeake Bay mainstem and portions of the major lower tributaries due to natural and human-caused conditions that cannot be remedied. The current dissolved oxygen criteria adopted by Maryland and Virginia into their water quality standards—$\geq$5 mg/l at all times and $\geq$4 mg/l minimum/$\geq$5 mg/l daily average, respectively—are unlikely to be achieved in deeper Chesapeake Bay tidal waters during the summer season where physical processes (such as water-column stratification and water circulation) and bottom bathymetry-related barriers prevent the replenishment with oxygenated waters.

As described below, a combination of natural and human-caused conditions prevents attainment of the dissolved oxygen concentrations necessary to meet the states' current aquatic life designated uses in portions of the Chesapeake Bay and its tidal tributaries. It should be noted that any of the six designated use removal factors specified in the EPA Water Quality Standards regulations (40 CFR 131.10[g]) and described in Chapter I can be employed, where appropriate, to justify changing a designated use. This chapter relies on two of those factors, but that does not prevent the states from using one or more additional factors in justifying refinements to their tidal-water designated uses.

The model simulation of all-forested and pristine watersheds and findings from scientific paleoecological records indicate that dissolved oxygen levels less than 5mg/l are a natural condition in some deeper waters of the Chesapeake Bay and its tidal tributaries during the summer. Furthermore, even where natural conditions could support a dissolved oxygen concentration of 5 mg/l, model simulations show that areas exist where current state standards are unlikely to be met due to irremediable human-caused conditions.

NATURAL CONDITIONS THAT MAY PREVENT ATTAINMENT OF CURRENT DESIGNATED USES

Evidence from the paleoecological record of the Chesapeake Bay Watershed and Water Quality model simulations of a pristine and all-forested Chesapeake Bay system indicates that natural conditions alone may prevent attainment of current uses. In the absence of monitoring data from periods before human settlement occurred, these findings and simulations provide the best available descriptions and estimates of the Bay's tidal-water quality under natural conditions.

Paleoecological Record of Natural Conditions

Dissolved oxygen levels vary naturally in lakes, estuaries and oceans over temporal and spatial scales due to many different biological, chemical and physical processes. In estuaries such as the Chesapeake Bay, freshwater inflow that influences water-column stratification; nutrient input and cycling; physical processes such as density-driven circulation; and tides, winds, water temperature and bacterial activity are among the most important factors. These processes can lead to large natural seasonal and interannual variability in oxygen levels in many parts of the Chesapeake Bay and its tidal tributaries.

Superimposed on this natural dissolved oxygen variability is a progressive increase in the intensity and frequency of hypoxia and anoxia over the past 100 to 150 years, most notably since the 1960s. This human-induced eutrophication is evident both from instrumental data and geochemical and faunal/floral 'proxies' of dissolved oxygen conditions obtained from the sedimentary record.

The instrumental record, while incomplete prior to the inception of the multi-agency Chesapeake Bay Monitoring Program in 1984, suggests that as early as the 1930s (Newcombe and Horne 1938) and especially since the 1960s (Taft et al. 1980), summer oxygen depletion has been recorded in the Chesapeake Bay. Officer et al. (1984), Malone (1992), Harding and Perry (1997) and Hagy (2002) provide useful discussions of the instrumental record of dissolved oxygen and related parameters such as chlorophyll *a* across this multi-decade data record.

At issue is whether, and to what degree, dissolved oxygen reductions are a naturally occurring phenomenon in the Chesapeake Bay. Long sediment core records (17 meters to greater than 21 meters in length) indicate that the Chesapeake Bay formed about 7,500 years ago (Cronin et al. 2000; Colman et al. 2002) when the rising sea level after the final stage of Pleistocene deglaciation flooded the Susquehanna channel. The modern estuarine circulation and salinity regime probably began in the mid- to late Holocene epoch, about 4,000-5,000 years ago (in the regional climate of the early Holocene, Chesapeake Bay's salinity differed from that of the late Holocene). This theory is based on the appearance of 'pre-colonial' benthic foraminiferal, ostracode and dinoflagellate assemblages. It is against this mid- to late Holocene baseline that that the post-European settlement and modern dissolved oxygen regime of the Chesapeake Bay can be viewed.

During the past decade, studies of the Chesapeake Bay's late Holocene dissolved oxygen record have been carried out using several proxies of past dissolved oxygen conditions, which are preserved in sediment cores that have been dated using the most advanced geochronological methods. These studies, using various indicators of past dissolved oxygen conditions, are reviewed in Cronin and Vann (2003) and provide information that puts the monitoring record of the modern Chesapeake Bay into a long-term perspective and permits an evaluation of natural variability in the context of restoration targets. The following types of measurements of oxygen-sensitive chemical and biological indicators have been used: nitrogen isotopes (Bratton et al. 2003); biogenic silica and diatom communities (Cooper and Brush 1991; Cooper 1995; Colman and Bratton 2003); molybdenum and other metals (Adelson et al. 2000; Zheng et al. 2003); lipid biomarkers; acid volatile sulfur (AVS)/chromium reducible sulfur (CRS) ratios; total nitrogen and total organic carbon (Zimmerman and Canuel 2000); elemental analyses (Cornwell et al. 1996) and paleoecological reconstructions based on dinoflagellate cysts (Willard et al. 2003); and benthic foraminiferal assemblages (Karlsen et al. 2000). Although space precludes a comprehensive review of these studies, and the time period studied and level of quantification vary, several major themes emerge, summarized below.

First, the 20th century sedimentary record confirms the limited monitoring record of dissolved oxygen, documenting that there has been a progressive decrease in dissolved oxygen levels, including the periods of extensive anoxia in the deep-channel region of the Chesapeake Bay that have been prominent during the past 40 years. Most studies provide strong evidence that there was a greater frequency or duration of seasonal anoxia beginning in the late 1930s and 1940s and again around 1970, reaching unprecedented frequencies or duration in the past few decades in the mesohaline Chesapeake Bay and the lower reaches of several tidal tributaries (Zimmerman and Canuel 2000; Hagy 2002). Clear evidence of these low dissolved oxygen conditions has been found in all geochemical and paleoecological indicators studied principally through their great impact on benthic and phytoplankton (both diatom and dinoflagellate) communities.

Second, extensive late 18th and 19th century land clearance also led to oxygen reduction and hypoxia, which exceeded levels characteristic of the previous 2,000 years. Best estimates for deep-channel mid-bay seasonal oxygen minima from 1750 to around 1950 are 0.3 to 1.4-2.8 mg/l and are based on a shift to dinoflagellate cyst assemblages of species tolerant of low dissolved oxygen conditions. This shift is characterized by a four- to fivefold increase in the flux of biogenic silica, a greater than twofold (5-10 milliliter^{-1}) increase in nitrogen isotope ratios ($_{15}$N) and periods of common (though not dominant) *Ammonia parkinsoniana*, a facultative anaerobic foraminifer. These patterns are likely the result of increased sediment influx and nitrogen and phosphorous runoff due to extensive land clearance and agriculture.

Third, before the 17th century, dissolved oxygen proxy data suggest that dissolved oxygen levels in the deep channel of the Chesapeake Bay varied over decadal and interannual time scales. Although it is difficult to quantify the extremes, dissolved oxygen probably fell to 3 to 6 mg/l, but rarely if ever fell below 1.4 to 2.8 mg/l. These paleo-dissolved oxygen reconstructions are consistent with the Chesapeake Bay's natural tendency to experience seasonal oxygen reductions due to its bathymetry, freshwater-driven salinity stratification, high primary productivity and organic matter and nutrient regeneration (Boicourt 1992; Malone 1992; Boynton et al. 1995).

In summary, the main channel of the Chesapeake Bay most likely experienced reductions in dissolved oxygen before large-scale post-colonial land clearance took place, due to natural factors such as climate-driven variability in freshwater inflow (Table III-1). However, this progressive decline in summer oxygen minima, beginning in the 18^{th} century and accelerating during the second half of the 20^{th} century, is superimposed on interannual and decadal patterns of dissolved oxygen variability. Human activity during the post-colonial period has caused the trend towards hypoxia and most recently (especially after the1960s) anoxia in the main channel of the Chesapeake Bay and some of its larger tidal tributaries. The impact of these patterns has been observed in large-scale changes in benthos and phytoplankton communities, which are manifestations of habitat loss and degradation.

Table III-1. Synthesis of five scientific experts' individual and collective findings on the history of anoxia and hypoxic conditions in Chesapeake Bay tidal waters.

Chesapeake Bay Dissolved Oxygen Criteria Team member Dr. Thomas Cronin, of the U.S. Geological Survey (USGS), surveyed five scientists[8] who have studied the history of anoxia and hypoxia in the Chesapeake Bay over decadal and centennial time scales, using geochemical and biological proxies from sediment cores and instrumental and historical records. The consensus of the five scientists is that the Chesapeake Bay was seasonally anoxic between 1900 and 1960. The seasonal anoxia was extensive in the deep channel and probably lasted several months. Similarly, between 1600 and 1900, the near-unanimous consensus is that the Chesapeake Bay was seasonally anoxic for probably weeks to months in the deep channel. One researcher had reservations about his group's earlier conclusion on definitive evidence of anoxia prior to 1900, but cannot exclude the possibility of anoxia during this period. Anoxia during the 1900–1960 period was probably geographically less extensive in the Chesapeake Bay and perhaps occurred less frequently (i.e., not every year) than after the 1960s. In addition to the geochemical and faunal proxies of past trends in oxygen depletion, experts cite the Sale and Skinner (1917) instrumental documentation of hypoxia and probable anoxia in the lower Potomac River in 1912.

For the period prior to European colonization (approximately 1600 AD), the consensus is that the deep channel of the Bay may have been briefly hypoxic (less than 2 mg/l), especially during relatively wet periods (which did occur, based on the paleo-climate record). Anoxia probably occurred only during exceptional conditions. It should be noted that the late 16th century and much of the 17th century were extremely dry periods, not conducive to oxygen depletion.

In sum, hypoxia, and probably periodic spatially limited anoxia, occurred in the Chesapeake Bay prior to the large-scale application of fertilizer, but since the 1960s oxygen depletion has become much more severe.

These experts also unanimously believe that restoring the Chesapeake Bay to mid-20th century, pre-1960 conditions might be possible but very difficult (one expert suggested an 80 percent nitrogen reduction was necessary), in light of remnant nutrients in sediment in the Chesapeake Bay and behind dams, likely increased precipitation as the climate changes, population growth and other factors. Most researchers believe that restoring the Chesapeake Bay to conditions prior to 1900 is either impossible, or not realistic, simply due to the fact that the temporal variability (year-to-year and decadal) in 'naturally occurring' hypoxia renders a single target dissolved oxygen level impossible to define.

Source: U.S. EPA 2003.

[8] T. M. Cronin (USGS, Reston, Virginia), S. Cooper (Bryn Athyn College), J. F. Bratton (USGS, Woods Hole, Massachusetts), A. Zimmerman (Pennsylvania State University), G. Helz (University of Maryland, College Park).

Water Quality Conditions under All-Forested and Pristine Watersheds

The natural relationships between processes on the land and in the water have been altered to such a degree that it is now difficult to discern natural conditions in this complex estuarine ecosystem. A 'natural' system is often considered to be the state prior to European settlement, although pre-contact Native American activities had an effect on the watershed and the Chesapeake Bay ecosystem as well. Pristine estuarine ecosystems no longer exist from which to reference water quality conditions since human-induced changes now affect even the most remote regions of the planet.

Given the research and monitoring data limitations for measuring natural water quality conditions, the Chesapeake Bay Program developed a paired set of model scenarios that represent its best effort to simulate water quality conditions prior to European settlement. By using the same model simulation tools to estimate pre-settlement water quality conditions as those used in other aspects of the attainability analyses presented in the *Technical Support Document*, reasonable comparisons could be made among estimated nutrient and sediment loading results and resulting simulated tidal-water quality responses.

The 'all-forest' scenario is a model simulation of what nutrient and sediment loads might occur if the entire Chesapeake Bay watershed was forested and atmospheric deposition reduced to 10 percent of the current loading rates. The storage of nutrients in the soil is still somewhat elevated under this scenario, and the nitrogen delivered to the Bay's tidal waters is actually greater than the atmospheric inputs to the watershed, owing to a 'draw-down' of nutrients in the soil. Shoreline erosion loading rates are maintained at current levels.

The 'pristine' scenario is a model simulation of what may have occurred under pre-settlement conditions. Atmospheric deposition is reduced to 10 percent of the current loading rates as in the all-forest scenario, but the soil storage of nutrients is also reduced, so that there is no 'draw-down' of nutrients during the simulation. In addition, steps were taken to restrict the conversion of particulate organic nitrogen to solution organic nitrogen. Shoreline erosion was set to only 10 percent of current levels to account for the pre-settlement presence of vast underwater grass beds and intertidal oyster bar breakwaters. Unlike most model simulations, no fertilizer applications to agricultural land, implementation of best management practices, septic loads or discharges from point sources are shown in either the all-forest or pristine scenarios.

Strengths and Limitations of the All-Forest and Pristine Scenarios

It is extremely difficult to determine the accuracy of the predictions at one-tenth the calibrated nitrogen loads for both the Chesapeake Bay Watershed and Water Quality models. Overall, the extremes of the all-forest and pristine scenarios push all three Chesapeake Bay models to their limits since they are calibrated to relatively current conditions.

The biological filtering capacities of a pristine Chesapeake Bay ecosystem are not factored into the current Bay models. One of these processes involved the vast extent of filter feeders, such as oysters, that consumed water-borne nutrients. In addition, oyster reefs provided habitat for an enormous range of other animals such as worms, snails, sea squirts, sponges, small crabs, and fishes, all of which are important components of the estuarine food web.

Existing reservoirs and shipping channels are present in the all-forest and pristine scenario landscapes and tidal waters because the Chesapeake Bay Watershed and Water Quality models were calibrated with these human alterations in place. As described in Chapter IV, these physical alterations can directly influence Chesapeake Bay tidal-water quality conditions.

Model-Simulated Natural Dissolved Oxygen Conditions

By anticipating these limitations when characterizing pre-European settlement effects on watershed loadings and tidal-water quality conditions, the paired all-forest and pristine scenarios present the best quantitative estimate of where and when "naturally occurring pollutant concentrations prevent the attainment of the use" (40 CFR 131.10[g]). The range of nutrient and sediment loads from these two scenarios yields the watershed partners' current best estimated range of "naturally occurring pollutant concentrations" and resulting Chesapeake Bay tidal-water quality conditions. Like all model results, the loads and water quality responses are most useful when compared to other scenarios. In this case, adequate comparisons can be made between the all-forest scenario results and those containing established levels of anthropogenic effects.

Figure III-1 illustrates the results of outputs from three scenarios of the Chesapeake Bay Water Quality Model–the pristine, all-forest, and E3 scenarios. The outputs provide the percent nonattainment of a 5 mg/l monthly average dissolved oxygen concentrations over 10 years of hydrology for the deep-channel, deep-water, open-water and migratory designated uses as discussed in Chapter IV. These dissolved oxygen concentrations are displayed over time (June 1 through September 30) and volume (Table III-2) of each respective designated use. Given the integration of the Chesapeake Bay Water Quality Model with water quality monitoring data, the outputs are currently generated as monthly averages although the water quality model operates on hourly time scales (Table III-2).

Under existing state water quality standards (see Chapter IV), the current dissolved oxygen criteria for Chesapeake Bay tidal waters in Maryland is "greater than or equal to 5 mg/l at all times," and in Virginia the Chesapeake Bay tidal-water criteria are "greater than or equal to 4 mg/l minimum, and greater than or equal to 5 mg/l daily average [see Table IV-1]." The analysis illustrated here for monthly average dissolved oxygen concentrations is less stringent of an averaging period than the current criteria in the states' water quality standards, given the monthly model output limitation.

Table III-2. Chesapeake Bay Watershed and Water Quality models.

The watershed and airshed models are loading models. As such, they provide an estimate of management actions through air controls, agricultural best mangement practices (BMPs), or point source controls which will reduce nutrient or sediment loads to the Chesapeake. The advantage of using loading models is that the full simulation through different hydrologies of wet, dry, and average periods can be simulated on existing or hypothetical landuse patterns. All of the Chesapeake Bay Program models used in the attainability analyses simulate the 10-year period of 1985 to 1994 (Linker et al. 2000).

Chesapeake Bay Watershed Model

The Chesapeake Bay Watershed Model is designed to simulate nutrient and sediment loads delivered to the Chesapeake Bay under different management scenarios (Donigian et al. 1994; Linker et al. 1996; Linker 1996). The simulation is an overall mass balance of nitrogen and phosphorus in the basin, so that the ultimate fate of the input nutrients is incorporation into crop or forest plant material, incorporation into soil, or loss through river runoff. The Chesapeake Bay Watershed Model has been in continuous operation within the Chesapeake Bay Program since 1982, and has had many upgrades and refinements since that time. The current version of the Watershed Model, Phase 4.3, is a comprehensive package for the simulation of watershed hydrology, nutrient and sediment export from pervious and impervious landuses and the transport of these loads in rivers and reservoirs.

Chesapeake Bay Water Quality Model

The complex movement of water within the Chesapeake Bay, particularly the density-driven vertical estuarine stratification, is simulated with a Chesapeake Bay hydrodynamic model of more than 13,000 cells (Wang and Johnson 2000). The Water Quality Model is linked to the hydrodynamic model and uses complex nonlinear equations describing 26 state variables of relevance to the simulation of dissolved oxygen, water clarity and chlorophyll *a* (Cerco 1993, 1995a, 1995b, 2000; Thomann et al. 1994; Cerco and Meyers 2000). Coupled with the Water Quality Model are simulations of settling organic material sediment and its subsequent decay and flux of inorganic nutrients from the sediment (Di Toro 2001), as well as a coupled simulation of underwater bay grasses in the shallows (Cerco and Moore 2001).

Integration of Monitoring and Modeling for Criteria Assessment

The observed data is used to assess criteria attainment during a 'base' period corresponding to the years of calibration for the Chesapeake Bay Water Quality Model, 1985–1994. The Chesapeake Bay Water Quality Model is used in scenario mode to determine the effect of changes in nutrient and sediment loads on water quality concentrations. A modified 1985–1994 observed data set is generated for each scenario using both the model and the observations. The same criteria attainment assessment process applied to the observed data is then applied to this 'scenario' data to determine likely criteria attainment under modified loading scenarios. For a full discussion of this procedure, see *A Comparison of Chesapeake Bay Estuary Model Calibration with 1985 – 1994 Observed Data and Method of Application to Water Quality Criteria* (Linker et al. 2002).

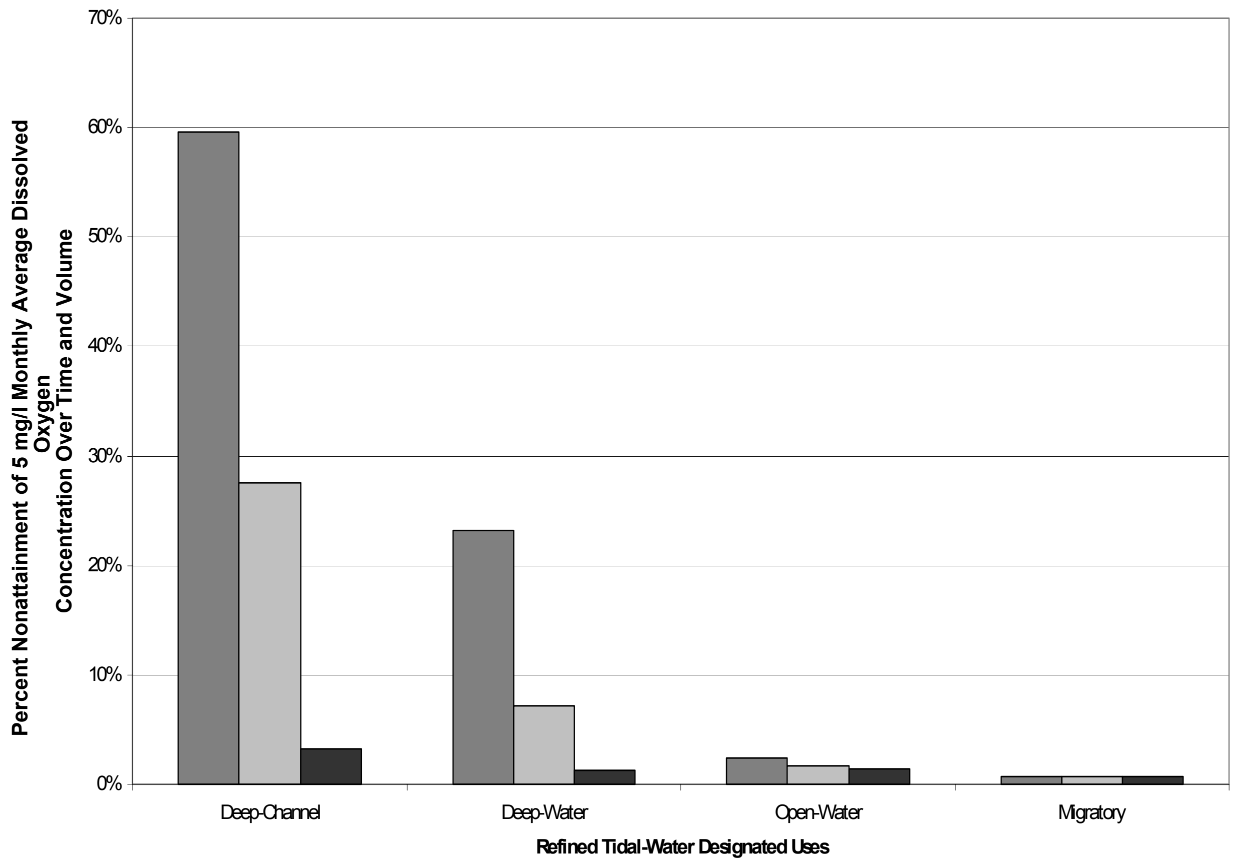

Figure III-1. Percent of nonattainment of a 5 mg/l monthly average dissolved oxygen concentration over the June through September period for the E3 (physically implausible) (dark grey bars), all-forest (light grey bars) and pristine (black bars) model scenarios by the refined tidal-water designated uses.

Results from the all-forest and pristine scenarios indicate that water quality in the deep-water and deep-channel portions of the current Chesapeake Bay designated uses are unlikely to meet existing Maryland and Virginia state dissolved oxygen water quality standards under natural conditions. Baywide, between 3 percent (pristine) and 28 percent (all-forest) of the volume and time over the summer months of the 10-year simulation period would likely not attain the current designated uses in the deep channel (Figure III-1). The current designated uses would likely not be attained up to 7 percent of the volume and time during the summer months under natural conditions in the deep-water habitats.

An examination of all-forest and pristine scenario results on a segment-by-segment scale documents similar findings. Table III-3 provides model-simulated results for the summer months–June through September–which have the lowest ambient dissolved oxygen concentrations. Results are presented for the 35 major Chesapeake Bay Program segments. In the upper, middle and lower central Chesapeake Bay, lower Potomac River, lower Rappahannock River and Eastern Bay segments there are natural barriers (e.g., water-column stratification, bottom bathymetry) preventing replenishment of dissolved oxygen to the deeper portions of the tidal waters under the all-forest scenario. For these segments under the all-forest scenario, nonattainment of the current state-adopted dissolved oxygen criteria assessed by the refined deep-water and deep-channel designated use habitats ranged up to 41 percent of the possible volume and time during the summer over the 10-year simulation period (Table II-3). Nonattainment values were down in the range of 4 percent to 5 percent under the pristine scenario.

These all-forest and pristine scenario findings are consistent with the conclusions reached through analysis of the *Paleoecological Records of Natural Conditions* described above.

Table III-3. Percent nonattainment of 5 mg/l monthly averaged dissolved oxygen concentrations over the June through September period from the E3, all-Forest and pristine model scenarios for the 35 major Chesapeake Bay Program segments by the refined tidal-water designated uses.

Chesapeake Bay Program Segment	Refined Tidal-Water Designated Use	E3	All-Forest	Pristine
Mainstem Upper Bay (CB1TF)	MIG	A	A	A
	OW	A	A	A
Mainstem Upper Bay (CB2OH)	MIG	A	A	A
	OW	A	A	A
Mainstem Upper Bay (CB3MH)	MIG	A	A	A
	OW	A	A	A
	DW	6	A	A
	DC	44	10	A
Mainstem Mid-Bay (CB4MH)	OW	A	A	A
	DW	25	2	A
	DC	81	41	4
Mainstem Mid-Bay (CB5MH)	OW	A	A	A
	DW	8	1	A
	DC	54	28	4
Mainstem Lower Bay (CB6PH)	OW	A	A	A
	DW	4	A	A
Mainstem Lower Bay (CB7PH)	OW	A	A	A
	DW	1	A	A
Mainstem Lower Bay (CB8PH)	OW	A	A	A
Patuxent Tidal Fresh (PAXTF)	MIG	A	A	A
	OW	A	5	5
Patuxent Mid-Estuary (PAXOH)	MIG	A	A	A
	OW	A	A	A
Patuxent Lower Estuary (PAXMH)	MIG	A	A	A
	OW	A	A	A
	DW	9	A	A
Potomac Tidal Fresh (POTTF)	MIG	A	A	A
	OW	A	A	A

Chesapeake Bay Program Segment	Refined Tidal-Water Designated Use	E3	All-Forest	Pristine
Potomac Mid-Estuary (POTOH)	MIG	A	A	A
	OW	A	A	A
Potomac Lower Estuary (POTMH)	MIG	A	A	A
	OW	A	A	A
	DW	8	A	A
	DC	50	11	A
Rappahannock Tidal Fresh (RPPTF)	MIG	A	A	A
	OW	A	A	A
Rappahannock Mid-Estuary (RPPOH)	MIG	A	A	A
	OW	A	A	A
Rappahannock Lower Estuary (RPPMH)	MIG	A	A	A
	OW	A	A	A
	DW	6	A	A
	DC	39	11	A
York Lower Estuary Piankatank	OW	A	A	A
York Tidal Fresh Mattaponi (MPNTF)	MIG	A	A	A
	OW	25	45	54
York Mid-Estuary Mattaponi (MPNOH)	MIG	A	A	A
	OW	48	56	59
York Tidal Fresh Pamunkey (PMKTF)	MIG	A	A	A
	OW	13	50	62
York Mid-Estuary Pamunkey (PMKOH)	MIG	A	A	A
York Lower Estuary (YRKMH)	MIG	A	A	A
	OW	A	A	A
York Lower Estuary (YRKPH)	OW	A	A	A
	DW	2	A	A
York Lower Estuary Mobjack	OW	A	A	A
James Tidal Fresh (JMSTF)	MIG	A	A	A
	OW	A	A	A
James Mid-Estuary (JMSOH)	MIG	A	A	A
	OW	A	A	A

Chesapeake Bay Program Segment	Refined Tidal-Water Designated Use	E3	All-Forest	Pristine
James Lower Estuary (JMSMH)	MIG	A	A	A
	OW	A	A	A
James Lower Estuary (JMSPH)	OW	A	A	A
Eastern Bay (EASMH)	MIG	A	A	A
	OW	A	A	A
	DW	10	A	A
	DC	61	22	A
Choptank Mid-Estuary (CHOOH)	MIG	A	A	A
	OW	A	A	A
Choptank Lower Estuary (CHOMH1)	MIG	A	A	A
	OW	A	A	A
Choptank Lower Estuary (CHOMH2)	MIG	A	A	A
	OW	A	A	A
Tangier Sound (TANMH)	OW	A	A	A
Pocomoke (POCMH)	OW	A	A	A

A = Applicable dissolved oxygen criteria fully attained; analysis based on monthly averaged dissolved oxygen concentrations 5 mg/l, 3 mg/l and 1 mg/l for open-water, deep-water and deep-channel designated uses.
DU = designated use; OW–open-water; DW–deep-water; DC–deep-channel.

HUMAN-CAUSED CONDITIONS THAT CANNOT BE REMEDIED WHICH APPEAR TO PREVENT ATTAINMENT OF CURRENT DESIGNATED USES

Beyond natural conditions, some human-related conditions and alterations of the watershed and tidal-water habitats must be considered in determining attainability of the current designated uses. To conduct this component of the UAA, where and when “human-caused conditions or source of pollution prevent the attainment of the use and cannot be remedied” (CFR 131.10[g]) must be defined.

The Chesapeake Bay Program developed a series of level-of-effort scenarios as a tool for assessing the Chesapeake Bay watershed’s potential for nutrient and sediment reductions (Appendix A). These scenarios range from a Tier 1 level, which will be in place by 2010 under current voluntary and regulatory programs, up to the fourth, ‘everything, everywhere by everybody,’ or the E3 scenario. Each scenario was based on 2010 projections of landuses, human population, agricultural animal populations, point source flows and septic systems.

Reduction actions defined in the E3 scenario were simulated using the Chesapeake Bay Program’s Phase 4.3 Watershed Model and the EPA’s Regional Acid Deposition Model (RADM), resulting in estimated airshed and watershed loads for nitrogen, phosphorus and sediment. The loading inputs from the airshed and watershed models were then fed into the Chesapeake Bay Water Quality Model to simulate the resulting dissolved oxygen concentrations.

The E3 scenario represents the limits of technology as known at the time of this analysis (Table III-4) and is acknowledged not to be physically plausible in all cases (Table III-5). This analysis assumes that any nutrient or sediment reductions *equal to or beyond* the levels defined through the E3 scenario can be considered to represent human-caused conditions that cannot be remedied and can be used for justifying why current designated uses cannot be met.

It is not possible to determine definitively human-caused conditions that cannot be remedied. However, the E3 scenario represents the Chesapeake Bay Program partners’ best effort to capture those conditions by removing as much subjectivity as possible in developing the scenario. Reported E3 scenario loading results from the Chesapeake Bay watershed’s land area, as a whole, represent theoretical minimum loads equal to or beyond which it would be extremely difficult, if not impossible, in many cases to achieve at this time. However, the reported E3 scenario-simulated water quality response can be improved if opportunities for further controls on shoreline erosion are incorporated.

It appears unlikely that current state water quality standards for dissolved oxygen can be achieved in significant portions of the Chesapeake Bay and tidal tributaries’ deep-water and deep-channel habitats (see Table III-3). As approximated by a 5 mg/l monthly average dissolved oxygen concentration, the existing state dissolved oxygen criteria protecting the current designated uses could not be attained in these habitats even after implementation of technologies and management practices at levels defined in the E3 scenario (see Figure III-1).

Table III-4. E3 scenario description.

The defined levels for technology and best management practices (BMPs) implementation in the 'everything, everywhere by everybody,' or the E3 scenario, are theoretical. There are no cost and few physical limitations applied to implementing BMPs for point and nonpoint sources. In addition, the E3 scenario includes new technologies, management practices and programs that are not currently part of Bay watershed jurisdictional pollutant control strategies. Appendix A details the assumptions and methodologies used in developing each technology and BMP-based implementation level in the three tier and E3 scenarios for all nutrient and sediment source categories.

<u>Agricultural Nonpoint Source Controls</u>

In the E3 scenario, it was assumed that the load from every available acre of the relevant land area was being controlled by a full suite of existing or innovative practices for most applied BMPs. In addition, management programs converted landuses from those with high-yielding nutrient and sediment loads to those with lower loads without regard to the economic viability of such changes. Every acre of cropland is conservation-tilled. Applications of fertilizers are set so that the crops do not receive more than 98 percent of their need, well below current recommended nutrient management rates. All other components of farm plans are fully implemented and the cropland is planted in cover crops to maximize nutrient reduction benefits.

The E3 scenario designates 100-foot riparian forest buffers on all unbuffered stream miles in the Chesapeake Bay watershed. A total of 25,000 acres of cropland are restored to wetlands. A quarter of the crop and hay areas not converted to riparian forest buffers or restored to wetlands are retired to grass conditions. The E3 scenario assumes there is rotational grazing on all pasture land and that all unbuffered streams through pastures are fully protected through both riparian buffers and fencing to exclude animals. The waste in animal feeding operations is controlled to a degree that there is no runoff. Another quarter of crop acreage in the Chesapeake Bay basin is replaced with long-term grasses that serve as a carbon bank and could be converted to energy through combustion.

<u>Urban/Suburban Nonpoint Source Controls</u>

To minimize storm water runoff from urban and suburban areas in the E3 scenario, all land projected to be developed in the next decade is employing environmental site design or low-impact development practices. In addition, all existing urban areas are retrofitted with a suite of practices to significantly reduce nutrient and sediment loads. Fifty-foot riparian forest buffers are placed along all currently unbuffered urban stream miles, while 100-foot buffers are found on all herbaceous lands that are not in agriculture. Also, all urban and nonagricultural grass acres do not receive nutrient applications from chemical fertilizers.

The E3 scenario calls for a 30 percent reduction in projected urban growth in Pennsylvania, Maryland, Virginia and the District of Columbia over the next decade to conform to commitments of the *Chesapeake 2000* agreement. Specifically for this model scenario, more urban areas are built up rather than out, and 30 percent of the forests are protected from development.

<u>Point Source Controls</u>

In the E3 scenario, all significant municipal dischargers maintain annual averaged effluent concentrations of 3 mg/l total nitrogen and 0.1 mg/l total phosphorus. All new septic systems employ denitrification technologies and are maintained through regular pumping to meet edge-of-septic-field nitrogen loadings that are one-quarter of typical loads. In addition, E3 atmospheric deposition assumes emission controls on utilities, industry and mobile sources beyond what the Clean Air Act requires.

Table III-5. E3 scenario possible over- and underestimations of attainable load reductions.

Physical Limitations In all appropriate circumstances, best management practice (BMP) implementation levels in the E3 scenario were applied to all relevant landuse areas or current limits of technology. In many cases and to remove the subjectivity in determining human-caused conditions that cannot be remedied, there were no physical limitations to employing the practices or programs. For many BMPs, the E3 implementation levels could not physically be achieved. For example, space may not be available for 50-foot riparian buffers in urban areas or certain developed lands may not allow for retrofitting with practices that attain pollutant reduction efficiencies used in the E3 scenario. In addition, certain crop types cannot be conservation-tilled and it may be physically impossible to completely eliminate runoff from animal feeding operations. It is also unlikely that every homeowner and farmer would efficiently apply fertilizers so that only the needs of the vegetation are met and that waterfront property owners would plant 50-foot buffers even if it were physically possible. As a whole, ‘feasible’ participation levels are not built into the E3 scenario. All of these instances are examples of where the E3 scenario may overestimate reductions. Underestimations of Load Reductions Attainable under the E3 Scenario By contrast, some BMP implementation levels physically could be even higher than those currently defined in the E3 scenario. For example, it is physically possible that more than 25,000 acres of cropland and hay in Chesapeake Bay watershed could be restored to wetlands. This limitation on wetland acres restored in the E3 scenario for Pennsylvania, Maryland and Virginia was used to reflect the *Chesapeake 2000* goal. As another example, 25 percent of cropland was replaced with long-term grasses that serve as a carbon bank and could be converted to energy through combustion. Benefits of a carbon sequestration program, in terms of lower pollutant loads, would increase as more agricultural land is converted. Conversion of more than 25 percent of cropland is physically possible. In addition, the 30 percent reduction in urban sprawl over a decade could be set at a higher level. This rate was employed in the E3 scenario to adhere to a *Chesapeake 2000* goal. The E3 scenario only includes shoreline erosion controls at current levels due to a current inability to define a ‘maximum’ limit that would not be entirely subjective. It has been demonstrated through modeling efforts that additional controls of shoreline erosion can significantly improve tidal-water quality. In general, much opportunity exists for reducing sediment and nutrient loads from eroding shorelines that is not reflected in the E3 scenario water quality model results. If greater BMP implementation levels than those designated in the E3 scenario could be physically achieved for any BMPs, pollutant loadings would decrease and there would be corresponding improved responses in water quality. For the most part, however, the E3 scenario did not consider real physical limitations to BMP implementation or participation levels.

FINDINGS AND CONCLUSIONS

The combined results of the E3, all-forest and pristine scenarios (see Figure III-1 and Table III-3) along with the scientific conclusions from the paleoecological record, strongly indicate that current state aquatic life designated uses cannot be achieved in the Chesapeake Bay's and tidal tributaries' deep-water and deep-channel habitats where natural physical processes and bottom bathymetry-related barriers prevent oxygen replenishment (see Chapter IV). Natural conditions, as well as human-caused conditions that cannot be remedied, would result in even higher levels of nonattainment of the states' existing 4 mg/l daily minimum and 5 mg/l daily averaged dissolved oxygen criteria than illustrated in Figure III-1 and summarized in Table III-3, given the application of a 5 mg/l monthly average dissolved oxygen concentration for this analysis.

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